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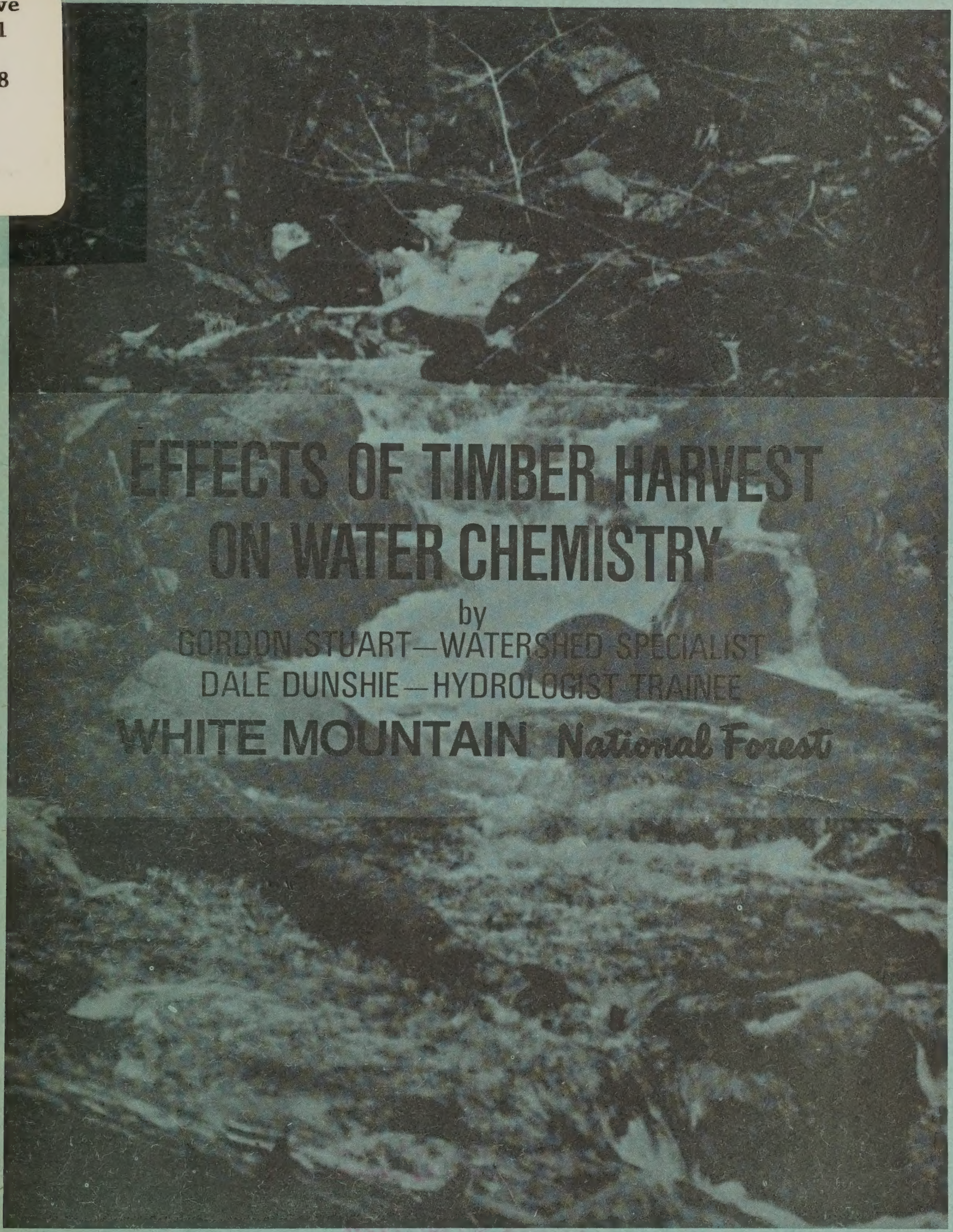

EFFECTS OF TIMBER HARVEST ON WATER CHEMISTRY

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HYDROLOGY PAPER

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PREFACE

The "Hydrology Papers" series is a publication of the Eastern Region of the Forest Service. The purpose is to rapidly distribute technical information pertinent to the water resource aspects of forest land management.

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ABSTRACT

During the period 1972-1974, chemical and biological monitoring of several small streams of the White Mountain National Forest was performed to assess nutrient release from the harvesting of Northern Hardwoods and Red Spruce on the Upper Mill Brook Sale, a harvest operation typical of this New England area. The sale totaled 267 acres and was divided into 9 cutting units with 102 acres of intermediate cuts and 165 acres of regeneration cuts. Units ranged in size from 12 to 40 acres. From results of Upper Mill Brook monitoring and the findings of other research work within the White Mountains, it can be concluded that (1) nutrient releases will not have adverse downstream impacts or conflict with water quality standards for municipal, recreation or fisheries uses, (2) timber harvesting has little effect on stream phosphorus concentrations, (3) timber management in the White Mountains will not significantly reduce over the long term soil nitrogen levels and (4) while nutrients can increase stream productivity near cut areas, sediment still appears to be the major potential pollutant associated with the National Forest timber program.

EFFECTS OF SILVICULTURAL ACTIVITIES ON WATER QUALITY

White Mountain National Forest

Introduction:

During the last 10 years, the effects of vegetative treatments on water chemistry have been measured at a number of areas in the White Mountains. For the most part, these studies have compared stream water chemistry between control and clear cut areas. Studies have been reported on research watersheds (Pierce 1970) and on National Forest Watersheds (Pierce 1972). More recently a study has been made on a strip cut research watershed (Hornbeck 1975).

Changes in water chemistry below cut areas are referred to as nutrient release or nutrient loss. Nitrate-nitrogen and calcium have been the most commonly reported nutrients. Ammonia, magnesium, potassium, sodium, and sulfate have also been reported in research papers.

In 1972, monitoring was started on the Upper Mill Brook Sale. This sale was typical of many on the National Forest and provided a good opportunity to monitor different treatments as there were several small streams draining the sale area. The intention was to provide data supplemental to that provided by Research. This was done by checking different areas, additional treatments, and additional nutrients.

Description of Area:

The Upper Mill Brook Sale is located in the Town of Carroll on the Ammonoosuc Ranger District. Rodney Rexford purchased the sale on 6/28/71 and began cutting in December 1971. The sale area totalled 267 acres and was divided into 9 cutting units with 102 acres of intermediate cuts and 165 acres of regeneration cuts. Units ranged in size from 12 acres to 40 acres. (Figure 1). The volume removed consisted of 1,675 MBF of Northern Hardwoods and 140 MBF of Red Spruce. Rubber-tired skidders were used for all skidding.

Description of sample points:

A. Downstream sample point 2500 acres.

1. 10-20 acres, intermittent stream.
   Treatment - A uniformly cut thinning with 90 square feet of basal area per acre left. Soils are medium textured and well drained in the two feet above the pan (Marlow Series). Cutting was done during January-February 1972.

2. Same as point 1, but cutting was done during February-March 1972.

3. 10-20 acres, intermittent stream.

Treatment - a clearcut with 30 square feet of basal area left in saplings of desirable species. The drainage contains a coarse textured, deep, well drained soil (Adam Series). Cutting was done during December 1971 - January 1972. No streamside buffer was left.

4. 20-30 acres, marginally perennial stream.

Treatment - Clearcut and cutting period same as point 3, but Marlow soils.

5. 10-20 acres, intermittent stream.

Treatment - clearcuts with an uncut buffer along the main stream channel. Cutting was done during June-September 1972. Marlow soils.

6. 10-20 acres, intermittent stream.

Treatment - A clearcut with no buffer. Generally an area of Marlow soils, but approximately four acres of wet poorly drained soils along the stream channel in the cut area. Cutting was done from September 1972 - February 1973.

7. 1000 acre drainage. There was a minor area of cutting on the fringes of this drainage. Sample point A was located downstream of this tributary because there was no place to sample the main stream between where stream 6 and 7 entered.

8. 30-40 acres, perennial stream. An uncut drainage of 60-80 year old northern hardwoods similar to the cut stands. Primarily Marlow soils, but some areas of poorly drained soils near the sample point. Spruce-fir cover type predominates on the poorly drained soils.

9. 20-30 acres, marginally perennial stream. An uncut drainage similar to point 8, but all Marlow soils with no spruce-fir component adjacent to the stream.

C. Up stream sample point 620 acre drainage.

On the small tributaries it is difficult to tell the exact watershed size because of a lack of relief between drainages. It is also difficult to tell exactly how much of each drainage was cut.

Sampling:

Samples were collected during the entire year with emphasis on the fall period. Previous monitoring indicated that 10 to 12 samples per year would be sufficient to show the major changes which were being reported.

Chemical samples were tested for Kjeldahl (organic) and nitrate-nitrogen, calcium, and phosphate. All samples were analysed in the R-9 Water Quality Laboratory. During the sampling period the laboratory shifted from testing Kjeldahl to testing total nitrogen. Initially only specific conductance was measured at points 3 and 6, but chemical analysis was added when changes began to occur. The number of samples analysed for phosphate were increased during the last few years.

Sample point C was originally set up as the control. Later points 8 and 9 were added to get a better indication of baseline quality on small streams.

Instantaneous flow measurements were recorded at point A to index runoff during sampling.

Aquatic insect samples were collected at points A, 4, and 5. Samples were collected each summer during 1972, 1973, and 1974. A fine mesh net was placed in the stream to collect insects dislodged when representative bottom sections were disturbed.

Results:

Data for seasonal analysis were separated by months as follows:

Season	Months
Winter	December, January, February, March
Spring	April, May, June
Summer	July, August, September
Fall	October, November

Conductance is a field measurement which indicates the concentration of ionized substances in the water. All the parameters which were affected by cutting affected conductance with the important exception of organic nitrogen.

Inspection of conductance plots in Figures 2, 3, and 4 indicates nutrient release varies with intensity of cutting, cutting unit layout, and soil type. Nutrient release from clearcut areas with sandy soils (point 3) and no stream buffer resulted in a surge of nutrients immediately after cutting, but returned to normal after two years. Clearcutting on a loamy soil (point 4) without a buffer resulted in a release which was similar to other reports (Pierce 1972). At point 4 the release occurred during a three year period with the second year being the highest. Clearcutting sites where streams run through organic soils (point 6) resulted in conductance levels equal to or less than those of the control. Here the release was in the organic nitrogen form which did not affect conductance. Values for the thinnings (points 1 and 2) and the clearcut with buffer (point 5) were similar. Conductance measurements indicate a release for the first two years following cutting.

Total nitrogen includes both organic and inorganic forms. Prior to July 1973 test results for nitrate-nitrogen and Kjeldahl-nitrogen were combined to determine total nitrogen. After that date, a test for total nitrogen was made.

Inspection of three-year mean values for total and nitrate nitrogen in Figure 5 indicates all cutting will accelerate nitrogen release. The effect of different types of cutting can be seen. Clearcuts without a buffer had the highest release. Clearcuts with buffers and thinnings were nearly the same. The clearcut with organic soils had the lowest average nitrogen release of any treatment. At point 6 nearly all the release was in the organic form. There was little difference in nitrogen levels between Mill Brook upstream, downstream or in tributary controls.

Seasonal plots of total nitrogen as shown in Figures 6, 7, and 8 are more variable than the conductance plots. The nitrogen release at point 4 is typical of other reports (Pierce 1972). However, the release at points 3, 5, and 6 are different. Since chemical sampling at points 1, 2, and 6 was started when conductances were high, it is assumed that the peak total nitrogen release was sampled.

The release from point 5 indicates the effect the buffer has in reducing stream concentrations during the growing season (Figure 7).

Figure 8 indicates upstream and downstream values. The peaks in the winter and spring of 1975 were probably due to weather conditions. Yet in the summer of 1973, a 30-year flood did not seem to affect concentrations.

Figure 9-13 indicate the seasonal relationships of total and nitrate nitrogen.

Calcium levels were not greatly influenced by cutting. In several streams there were single high values, but only at point 4 was the increase persistent enough to show up in the three-year average. Points 5 and 6 may have had calcium levels which were naturally low. Figure 15 indicates the similar pattern of calcium and nitrogen release as reported by Stone (1975).

Phosphate data is limited during the first two years. However, analysis of the available data indicates the sale had little influence on the phosphate release. A plot of phosphate data for points 3 and 4 against points 8 and 9 graphically illustrates that monthly concentrations are similar (Figure 16).

Sample period mean values are shown in Table 1. Phosphate levels at point 3 are slightly higher than points 8 and 9. All other treatments had lower phosphate values than the control. It is also interesting to note that all tributaries had much higher values than the main stream and the downstream level was only slightly affected by the tributary input. However, none of phosphate means proved to be significantly different from the control (Table 2).

Seasonal means for the three-year period are shown in Table 3. In terms of mean values there is no consistent pattern of seasonal change especially in nitrate nitrogen which was consistently highest in the winter.

Aquatic insects were sampled during 1972, 1973 and 1974 to determine if the expected nutrient release would affect aquatic life. The results, in Table 4, indicate a change at points 4 and 5. Whether this change was due to the increased flows or the increased nutrients cannot be determined. Stream flow at point 5 became perennial after cutting similar to what the flow probably was at point 4 before cutting. By inference, the increase in flow is believed to be more important than the increase in nutrients.

Discussion:

It is evident timber cutting increases nitrogen concentrations in small streams draining cut areas. The increase is influenced by the intensity of cutting and soil conditions. Stream buffer strips will reduce the amount of nitrogen which reaches streams during the growing season on shallow soils.

In comparing nitrogen levels below clearcuts on Mill Brook and those reported elsewhere (Pierce 1972), differences in treatments need to be taken into account. For example, the drainage above point 4 is quite similar to Hubbard Brook watershed 101. However, watershed 101 was a complete clearcut on the entire 25-acre drainage, whereas about 80% of the drainage above point 4 was clearcut and 30 square feet of basal area was left. The results at point 4 are typical of National Forest operations because seldom is an entire 30-acre drainage completely clearcut. Cutting is based on stand conditions which usually do not conform to the watershed boundary.

Total nitrogen provides a better indication of the effects of cutting than the nitrate constituent. If nitrate alone had been measured at point 6, the results would have been misleading. Nitrate is mobile in soils and is readily available to plants, but to get the complete picture of how cutting affects nitrogen levels, the organic portion must be measured. The proportions of organic and inorganic nitrogen can vary as water moves down a drainage. In the Bowl Research Natural Area, three streams averaged 0.60 mg/l total nitrogen and 0.23 mg/l nitrate nitrogen near their source at 3500 feet. At 2500 feet, total was 0.68 mg/l and nitrate 0.51 mg/l. Measurements downstream from point 6 would probably show an increase in the nitrate portion of total nitrogen.

Although phosphate was not tested on all samples, there does not appear to be any change due to cutting. Phosphate has been checked on a number of sales and the results have ~~generally~~ been similar to Mill Brook. However, phosphate levels in intermittent streams on the Betty Brook Timber Sale (Androscoggin R.D.) were an exception. Betty Brook sample points averaged 0.112 and 0.122 mg/l phosphate over a three-year period (Table 5).

Where downstream checks were made, phosphorus levels were generally within normal ranges (Table 7). The downstream phosphate levels on Mill Brook and the East Branch (Saco RD) not only indicate the effect of dilution, but also indicate that phosphorus attached to stream particulate matter does not create a downstream problem.

Table 7. Means and Standard Deviation of Phosphate Data for Mill Brook and Other Streams.

Stream	Drainage Area	Percent with Sale Activity	Number of Samples	Mean Mg/l	Standard Deviation
West Br. Mad	3,200	0	20	.033	.037
Upper Swift	13,000	0	34	.031	.031
East Br. Saco	7,200	30	72	.041	.031
Mill Brook A	2,500	10	25	.044*	.033
Mill Brook C	600	0	24	.038	.032
Bowl Drainages	30-1000	0	24	.037	.028

* Point A and C are not significantly different at the .05 confidence level.

Nitrogen is the primary nutrient which is affected by cutting. The release of nitrogen has been reported to originate in the humus (Stone 1975). Frequently the term "disturbance" has been used to refer to the mechanism which starts the release. One type of disturbance occurs when a site is exposed to sunlight, warmer temperatures, and high soil moisture levels. Another type of disturbance would be actual mechanical disturbance of surface layers. Nutrients were monitored below an area of scarification on the Bell Mountain Timber Sale (Evans Notch R.D.). A small portion of the sale which was cut in the summer of 1971 was scarified in the summer of 1972. The monitoring started in 1973 indicated no effect from the scarification (Table 6). The portion of the Betty Brook sale area which was disturbed during logging was also checked and it was determined that mineral soil was exposed in 2% of the area. It does not appear that mechanical disturbance is a significant factor in nitrogen release as has been measured near cutting units.

Concern has been expressed about downstream impacts on water quality. In 1971, downstream nitrogen levels were checked below a clearcut on the Gale River municipal watershed. This cutting area had the highest nitrate levels of the sales reported by Pierce (1972). Nearly 25% of an 1100 acre tributary had been clearcut.

Table 8. Gale River Sale (Based on three sets of paired samples).

Sample Point	Drainage Area (Acres)	NO_3-N	Ca - mg/l -	PO_4
Cutting Units	10	3.10	5.6	0.018
Scarface Brook	1100	0.53	3.1	0.018
South Branch of Gale	4900	0.17	1.9	0.024

The results on Mill Brook, Gale River, and the East Branch of Saco (Table 9) indicate that limiting the portion of a drainage which is clearcut is an effective way of maintaining downstream quality.

Nitrogen loading cannot be accurately determined for each Mill Brook sample point because flow was only measured at Point A and the watershed boundaries of the small streams cannot be accurately located. The following table indicates approximate loading values for sampling points where flow was measured.

Table 10. Total Nitrogen and Phosphorus Loading Values

Stream *	Average Sample Flow Cfs	Estimated Av. Annual Flow Cfs	Projected Nitrogen lbs/ac/yr	Projected Phosphorus lbs/ac/yr
West Br Mad	16	15	3.7	.080
Upper Swift	210	101	3.2	.064
East Br Saco	41	23	2.5	.097
Mill Brook A	5	8	4.5	.111

* Refer to Table 7 for additional information on these sample points.

Loading is important when the input and output of nitrogen is discussed. Nitrogen loss from cut stands has generally been compared to the output from stands with vigorous growth. In the last two years, nitrogen loss from old growth stands in the White Mountains has been investigated as a result of Leaks (1974) work in the Bowl Research Natural Area. Martin (1975) report indicates there are several streams in the Bowl where input nearly matches output and he concludes that a steady state has been reached. A paper by Vitousek (1975) discusses the relation between biomass accumulation and nitrogen output. When biomass is increasing output will be less than input, but when stands reach an age where biomass ceases to accumulate, input and output will balance.

Questions have been raised about the long term effects of timber cutting. By comparing nitrogen loss from manipulated and natural stands it may be possible to project these long term effects. While the Bowl may be in a steady state, vegetation is undergoing long term cycles of "growth and destruction" as described by Vitousek.

The following rough comparison can be made utilizing existing data. These loading figures were determined on short term studies at a few selected locations and are only used to demonstrate long term effects. Stream flows for these loading figures were not determined on site in all cases.

Table 10. Projection of Available Loading Data over a Rotation.

Manipulated Condition:

Stand Age	Years of Release	NO_3-N kg/ha	Total kg/ha
0-5	5	47 (1)	235
6-60	55	3.6 (2)	198
61-65	5	5.8 (3)	29
66-80	15	3.6	54
81-85	5	5.8	29
86-100	15	3.6	54
101-105	5	5.8	29
106-120	15	3.6	54
		Total Output	682 kg/ha

Steady State - Martins Bowl data:

6-7 kg/ha/year of NO_3-N for 120 years equals a total output of 720-840kg/ha

(1) 47 kg/ha is a two-year average reported by Pierce (1972) for the Gale River Sale.

(2) 3.6 kg/ha is an 11-year average of 6 untreated watersheds with 70-year old stands (Likens 1972).

(3) 5.8 kg/ha is a three-year average of Mill Brook 1 and 2 as a proportional increase of uncut stands when applied to the 3.6 kg/ha.

The manipulated case is probably the worst situation. Typically northern hardwood stands are thinned twice during the rotation period. Moreover, many researchers have indicated NO_3-N releases return to precut levels by the fourth year.

The difference between the manipulated and steady state is due to the rough data used. If more detailed data were available, items like the transportation of nitrogen off site in products could be taken into account.

Management Interpretations:

In reviewing results of Mill Brook and other work in the White Mountains during the last five years, several conclusions can be made about the effects of the White Mountain National Forest Timber Management Program.

1. Nutrient release from the timber program will not have an adverse downstream impact or conflict with water quality standards for municipal, recreation or fishery use. Monitoring has repeatedly demonstrated that nitrogen is the primary nutrient affected and changes in nitrogen levels are isolated to the vicinity of the treatment. While the localized changes in nitrogen can be dramatic, it is not critical to water quality where phosphorus is limiting.

2. The fact that timber harvest has little effect on phosphorus levels is most important. Phosphorus has been recognized as the limiting factor in eutrophication of New Hampshire lakes (NH-WSPCC 1976). Present data gives a nitrogen/phosphorus ratio of 15/1 to 50/1 for streams on the Forest indicating that phosphorus is limiting.

3. There are good indications the current timber management plan (1974-1982) will not significantly reduce the long term nitrogen levels in the soil because a 120 year rotation is used for northern hardwoods and high quality saw timber is emphasized. However, management will affect the timing of nitrogen release.

4. There is obviously a critical point where short rotations and complete utilization of vegetation will begin to deplete the nitrogen capital. With present knowledge it appears possible to begin determining where this critical point is for different site and vegetation conditions. This type of interpretation should be made.

5. With all the attention on nutrients one cannot lose sight of the fact that sedimentation is the major potential pollutant associated with the National Forest timber program. While nutrients may increase water productivity near cut areas, sediments will adversely affect recreation uses, fish habitat, and water supply. By using good management practices and keeping cut areas small and dispersed, natural levels of water quality can be maintained in fishable size streams.

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Table 1. Sample Period Means and Ranges for Calcium, Total Nitrogen, Nitrate Nitrogen, Phosphate, and Phosphorus for Period: June 1972 to December 1975.

	Mill Bk Above (C)	Small Uncut Tributaries (8&9)	Thinnings (1&2)	Clearcut (3)	Clearcut (4)	Clearcut w/Buffer (5)	Clearcut Organic Soil(6)	Mill Bk Below (A)
			Calcium (Mg/l)					
Mean	2.16	2.85	2.73	2.91	3.31	2.57	2.07	2.56
High	2.90	4.10	4.38	5.81	4.40	3.32	3.50	3.40
Low	1.60	2.10	0.80	2.00	2.40	1.90	1.70	2.00
s*	0.30	0.45	0.51	0.75	0.49	0.41	0.38	0.38
			Total Nitrogen (Mg/l)					
Mean	0.67	0.71	0.92	1.32	1.50	0.94	0.81	0.62
High	4.20	2.88	2.50	3.55	3.40	2.92	4.10	1.80
Low	0.07	0.15	0.13	0.23	0.33	0.19	0.13	0.08
s	0.69	0.50	0.57	0.78	0.81	0.74	0.78	0.41
			Nitrate Nitrogen (Mg/l)					
Mean	0.27	0.23	0.45	0.79	0.96	0.39	0.23	0.23
High	1.02	1.21	2.10	2.55	2.48	1.51	1.35	0.80
Low	0.04	0.06	0.01	0.01	0.08	0.01	0.01	0.05
s	0.22	0.16	0.32	0.70	0.61	0.44	0.31	0.17
			Phosphate (Mg/l)**					
Mean	.038	.075	.055	.081	.055	.058	.066	.044
High	.108	.364	.338	.392	.288	.288	.505	.143
Low	.004	.005	.001	.006	.007	.002	.008	.013
s	.032	.075	.061	.083	.060	.063	.104	.033

*s = standard deviation

** Phosphate x .326 equals Phosphorus in mg/l

Table 2. T-Test of Sample Point Three Year Means for Phosphate, Calcium, Total and Nitrate Nitrogen at the .05 Level.

	Sample Point	Control	Significant	Not Significant
Total Nitrogen				
	A	C		X
	1&2	8&9		X
	3	8&9	X	
	4	8&9	X	
	5	8&9	X	
	6	8&9	X	
Nitrate Nitrogen				
	A	C		X
	1&2	8&9	X	
	3	8&9	X	
	4	8&9	X	
	5	8&9		X
	6	8&9		X
Calcium				
	A	C	X	
	1&2	8&9		X
	3	8&9		X
	4	8&9	X	
	5	8&9	X (Lower)	
	6	8&9	X (Lower)	
Phosphate				
	A	C		X
	1&2	8&9		X
	3	8&9		X
	4	8&9		X
	5	8&9		X
	6	8&9		X

Table 3. Seasonal Mean Concentrations for Calcium, Total Nitrogen, and Nitrate Nitrogen for Period: Summer 1972 to Fall 1975.

	Mill Bk Above (C)	Small Uncut Tributaries (8&9)	Thinning (1&2)	Clearcut (3&4)	Clearcut w/Buffer (5)	Clearcut Organic Soil(6)	Mill Bk Below (A)
				Calcium (Mg/1)			
Winter	2.14	2.62	2.75	3.26	2.68	2.06	2.16
Spring	2.11	2.75	2.67	2.94	2.68	1.98	2.05
Summer	2.28	3.03	3.05	3.15	2.75	2.14	2.14
Fall	2.19	3.27	3.02	3.48	2.79	2.08	2.77
				Total Nitrogen (Mg/1)			
Winter	.91	.61	.87	1.94	1.75	.86	.56
Spring	.57	.50	.86	1.26	1.13	.97	.88
Summer	.65	.81	.80	1.38	.59	.66	.63
Fall	.50	.85	1.20	1.58	.82	.89	.50
				Nitrate Nitrogen (Mg/1)			
Winter	.41	.30	.58	1.32	1.08	.37	.34
Spring	.33	.25	.38	.74	.43	.32	.33
Summer	.13	.22	.33	.76	.04	.07	.13
Fall	.21	.22	.37	.86	.21	.19	.23

Seasonal means cannot be averaged for annual mean because the number of samples varies between seasons.

Table 4. Benthic Animal Diversity

	Number of Genus/Species Identified				
	7/7/72	8/8/72	6/28/73	7/2/74	8/20/74
			Mill Brook A		
Order					
COLEOPTERA	2	2	2		3
DIPTERA	6	5	5	7	9
EPHEMEROPTERA	7	6	4	5	3
HEMIPTERA	1	3			1
LEPIDOPTERA		1		1	1
ODONATA		1			1
PLECOPTERA	3	4	4	5	3
TRICHOPTERA	6	9	7	6	5
Class					
ARACHNID	2	1			1
NEMATODE				1	1
Total	27	32	22	25	28
			Mill Brook 4		
Order					
COLEOPTERA	1	2	2	1	4
COLLEMBOLA	1				
DIPTERA	2	6	4	8	7
EPHEMEROPTERA	2	3	6	5	3
HEMIPTERA		1			3
LEPIDOPTERA			1		1
ODONATA				1	
PLECOPTERA	3	1	4	3	2
TRICHOPTERA	4	6	7	5	5
Class					
ARACHNID	1	1	1		
ANNELID	1				
Total	15	20	25	23	25
			Mill Brook 5		
Order					
COLEOPTERA			1		
DIPTERA	2	Dry	5	7	Dry
EPHEMEROPTERA			2	3	
HEMIPTERA					
LEPIDOPTERA					
ODONATA					
PLECOPTERA	1		3	1	
TRICHOPTERA	4		5	3	
Class					
ARACHNID				1	
OLIGOCHETE				1	
Total	7		16	16	

Table 5. Betty Brook Timber Sale

Date	Clearcut Point 1 Cond	NO_3-N	Total N	Ca	PO_4	Clearcut Point 2 Cond	NO_3-N	Total N	Ca	PO_4
5/9/73	26	.01	.29	1.3		26	.01	.69	1.4	
8/15/73	43	.04	.19	3.1	.105	100+	.08	.54	4.0	.170
9/26/73	41	.09	.24	3.0	.048	95	.05	.48	3.1	.232
10/24/73	40	1.26	1.38	3.1	.138					
11/9/73	46	1.85	1.90	3.3	.022	44	1.58	1.69	2.4	.017
5/30/74	31	.77	.81	2.5	.028	27	.38	.64	1.8	.038
8/6/74	40	.14	1.50	2.4	.246	41	.16	3.00	2.1	.188
10/22/74	33	.65	.98	2.6	.046	35	.39	.97	2.9	.160
11/14/74	36	.72	1.32	2.4	.042					
4/18/75	28	.41	.54	2.4	.113	27	.27	.50	2.0	.030
6/10/75	33	.02	.14	2.2	.390	36	.01	.10	2.2	.139
6/26/75	31		.38	2.2	.050					
Mean	36	.54	.81	2.5	.112		.33	.96	2.4	.122

Table 6. Bell Mountain Timber Sale

Date	Control Cond	NO_3-N	Total N	Ca	PO_4	Below Scarification Cond	NO_3-N	Total N	Ca	PO_4
5/8/73	22	.02	.14	1.0		30	.01	.74	1.8	
5/31/73	21	.01	2.56	1.8		30	.63	.93	2.1	
6/26/73	29	.22	.49	2.0		22	.05	.32	1.6	
10/2/73	25	.03	.28	2.3	.057	30	.09	.17	2.8	.078
11/7/73	25	.05	.18	2.0	.009	32	.24	.47	2.6	.012
5/30/74	26	.05	.19	1.5	.019	22	.15	.38	1.9	.035
7/31/74	26	.04	.67	2.0	.068	27	.08	.56	1.9	.068
8/8/74		.01	.60	2.4	.076		.02	.95	2.8	.091
10/30/74	27	.01	.37	2.1	.113	29	.02	.89	2.5	.025
Mean	25	.05	.61	1.9	.057	28	.14	.60	2.2	.052

Table 9. Annual Summary of Water Quality Data for East Branch of Saco.

Year	No. of Samples	Conductance units	Total Phosphate mg/1	Organic Nitrogen mg/1	Nitrate Nitrogen mg/1	Calcium mg/1	Sodium mg/1	Magnesium mg/1
1967	2	21			.08		1.25	
1968	7	21	.020	.04	.07		1.25	
1969	13		.053	.11	.07	1.36	1.04	.45
1970	3		.051	.14	.12	1.57	.89	.41
1971	11	23	.030	.22	.14	1.34	1.12	.36
1972	11	22	.025	.14	.16	1.45	2.11	.42
1973	10	21	.052	.19	.18	1.31	2.51	.29
1974	10	21	.054	.64*	.12	1.37	1.12	.23
1975	8	21	.045	.16*	.10	1.25	1.08	.36

* Calculated from the total nitrogen test.

Timber sales occurred in the 7,200-acre drainage from March 1968 to October 1972.

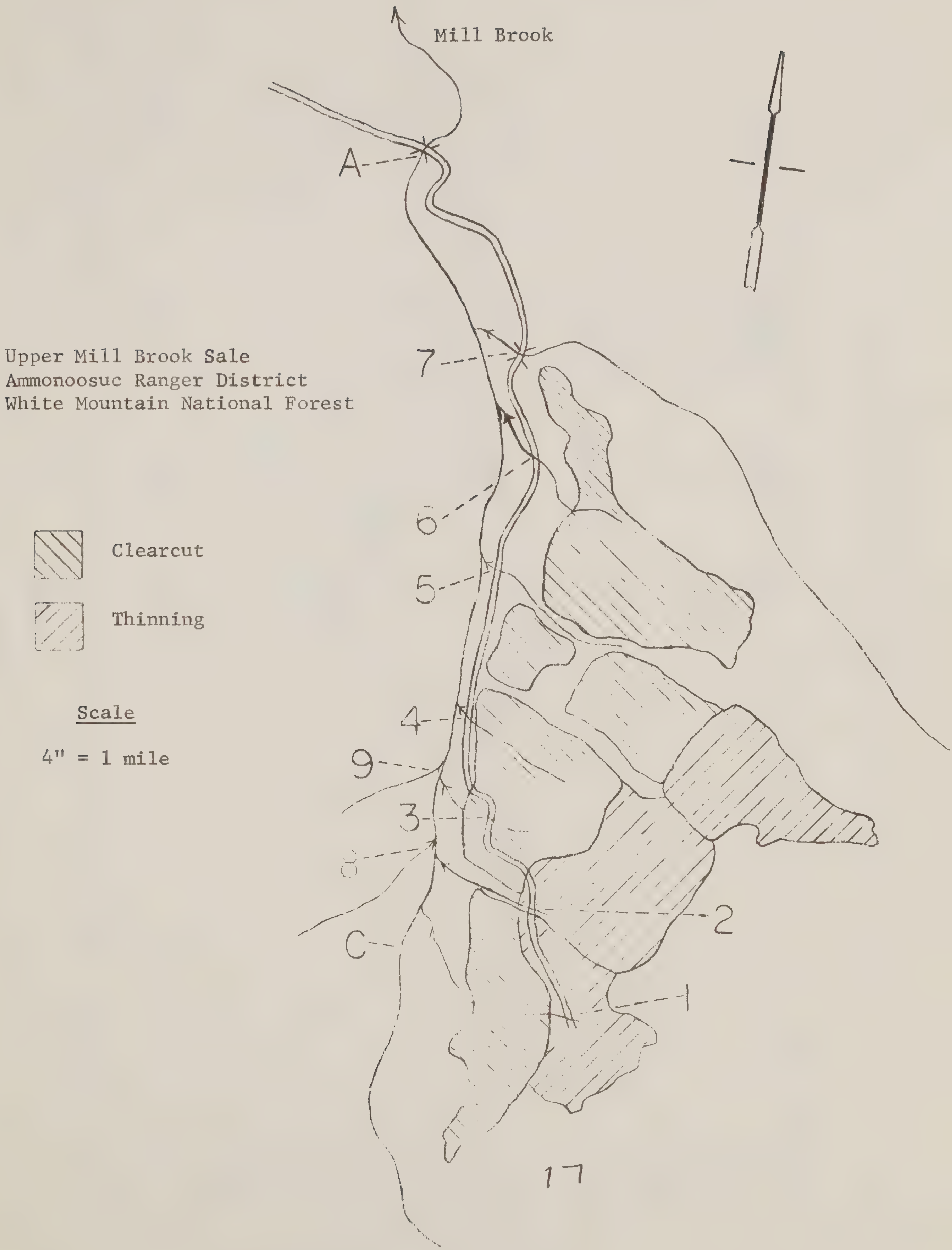

Figure 1. Upper Mill Brook Timber Sale

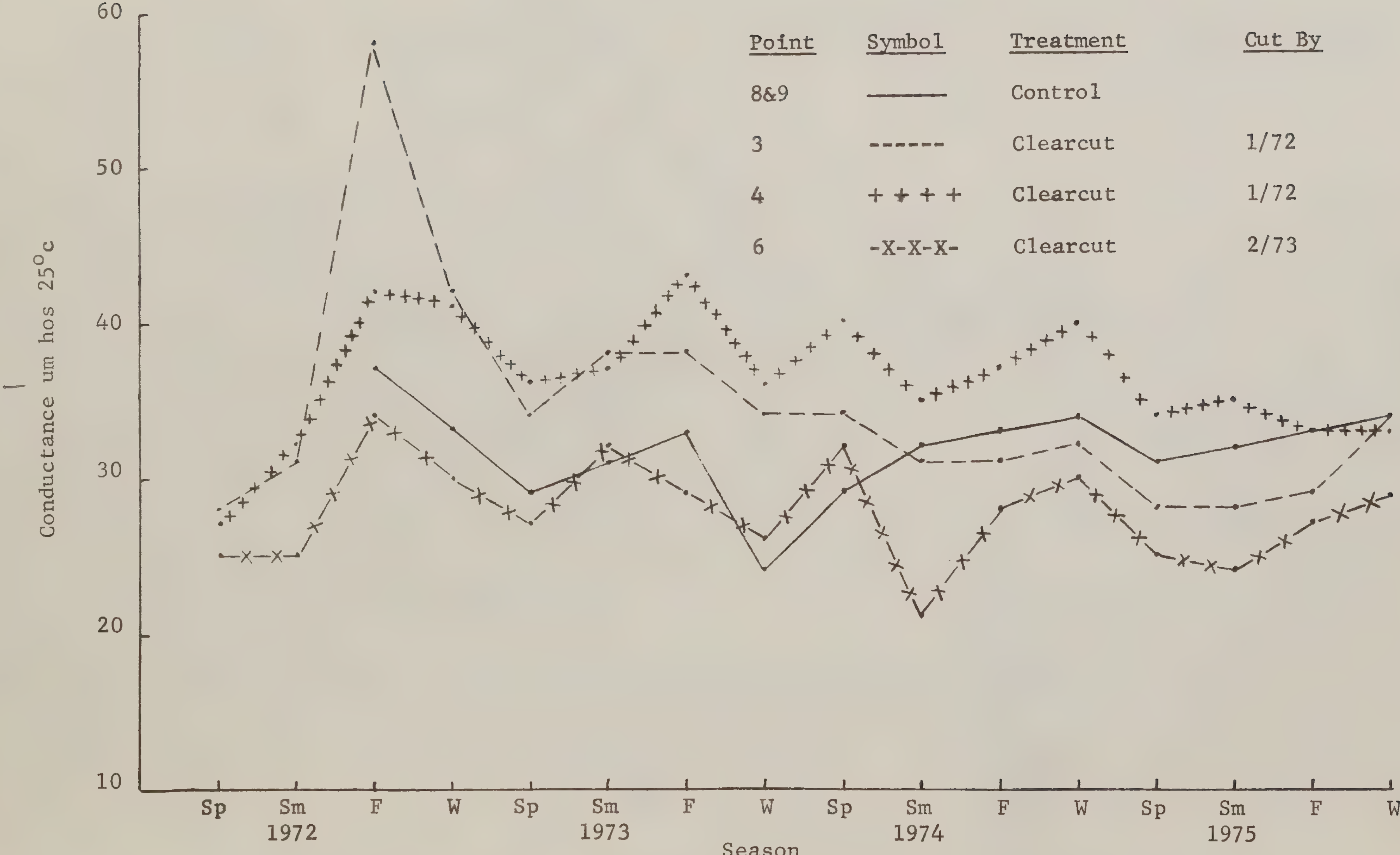

Figure 2. Mean Seasonal Specific Conductance - Clearcuts

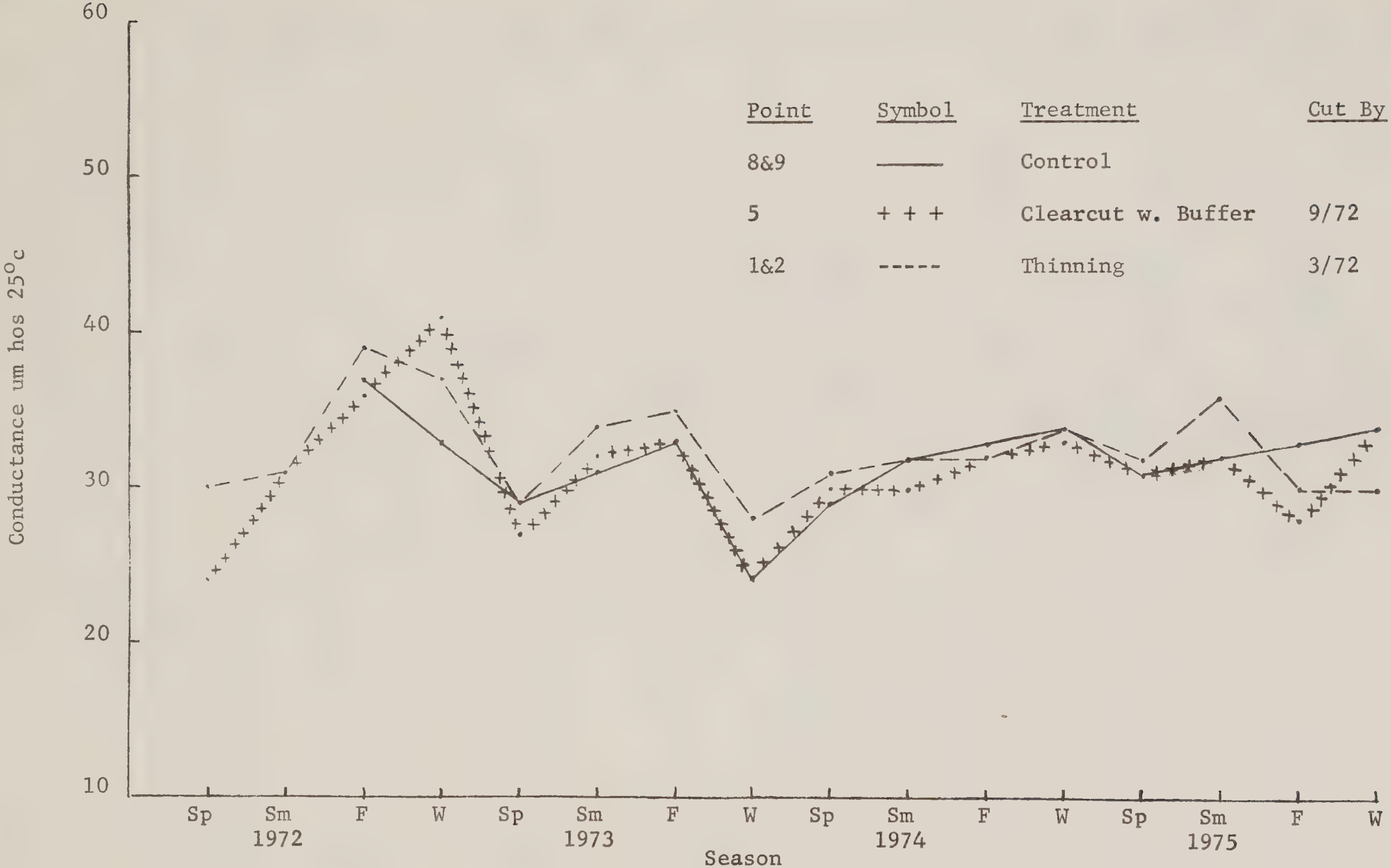

Figure 3. Mean Seasonal Specific Conductance - Other Cuts

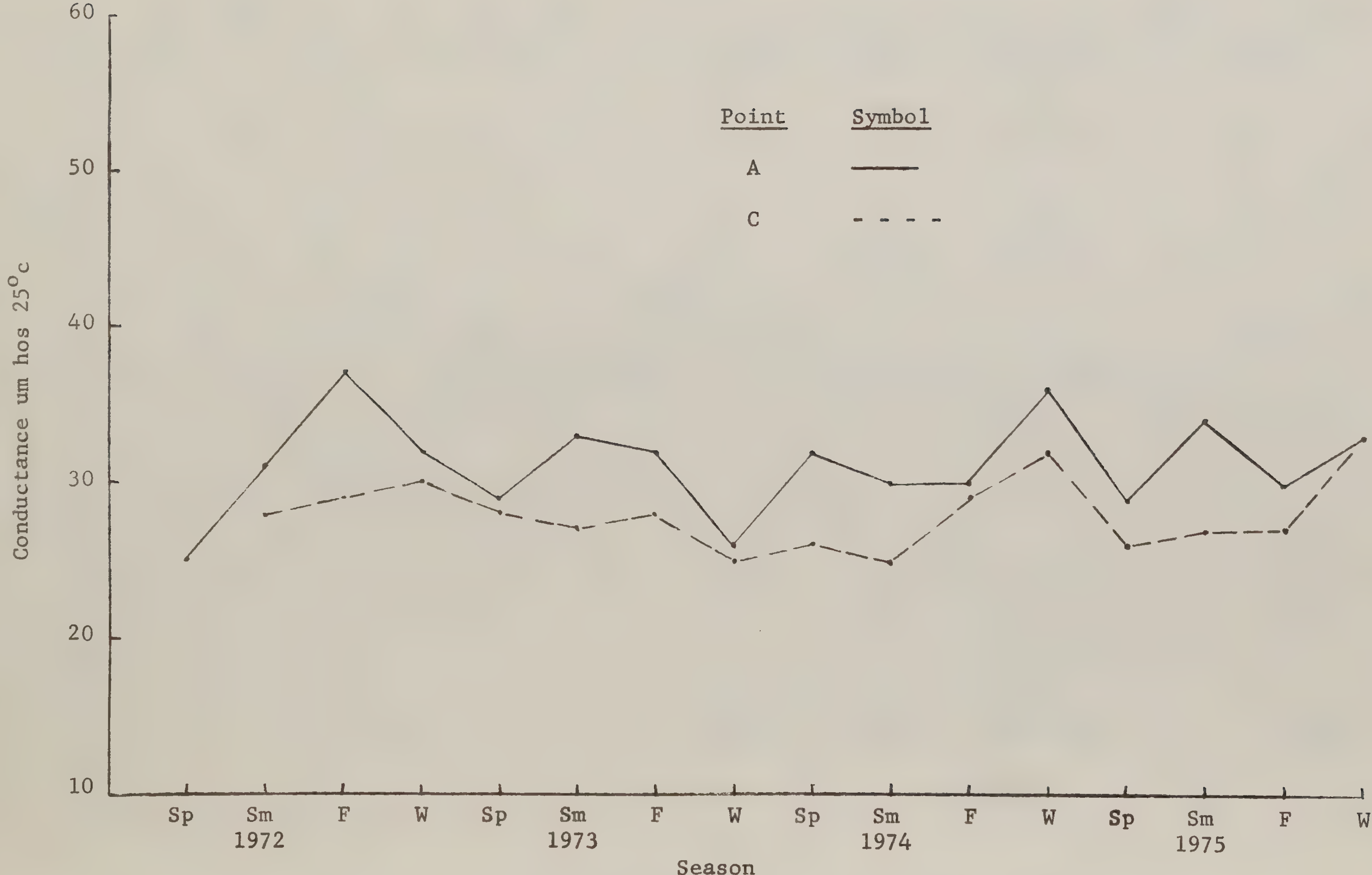

Figure 4. Mean Seasonal Specific Conductance - Main Stream

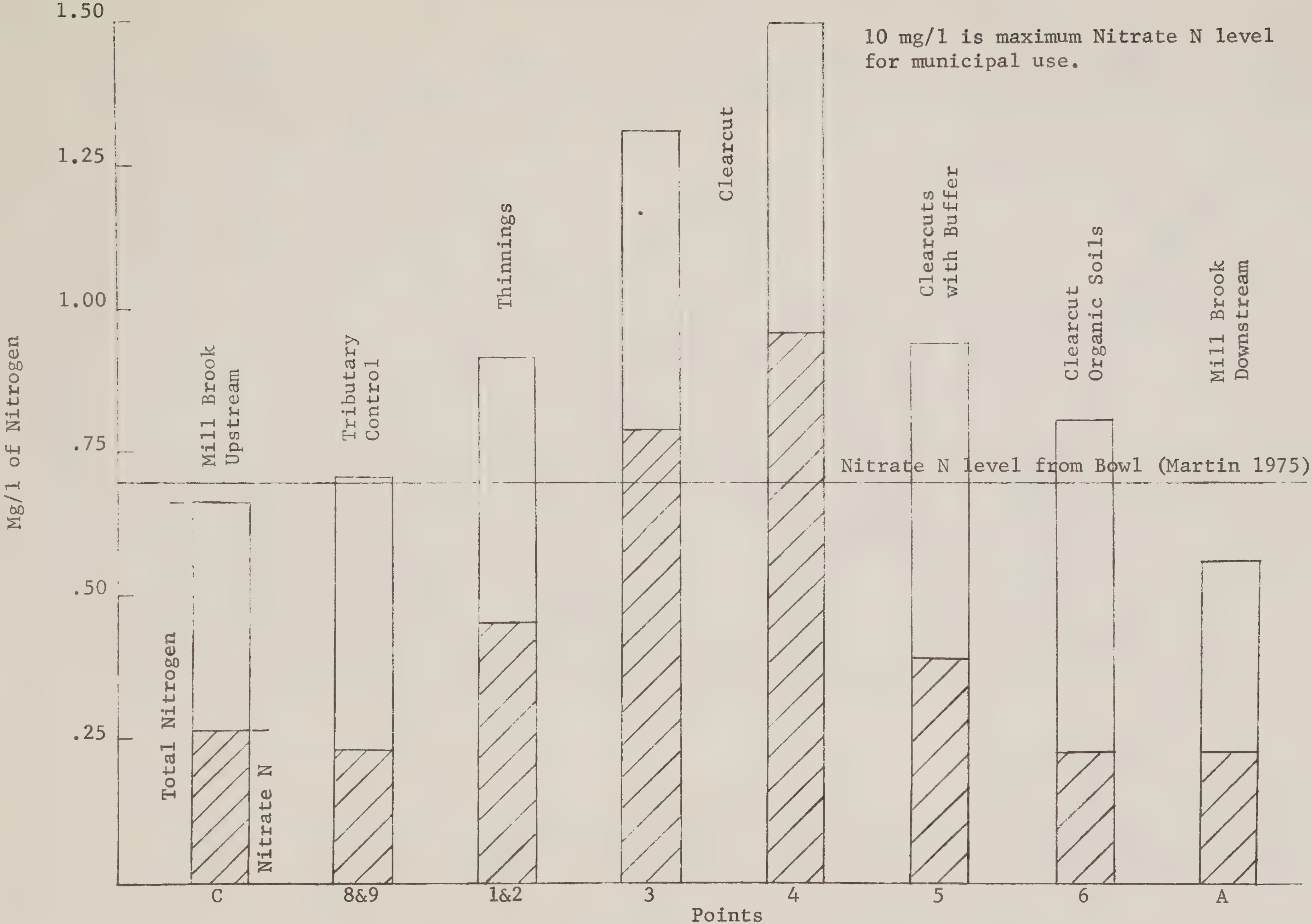

Figure 5. Three Year Means - Total and Nitrate Nitrogen

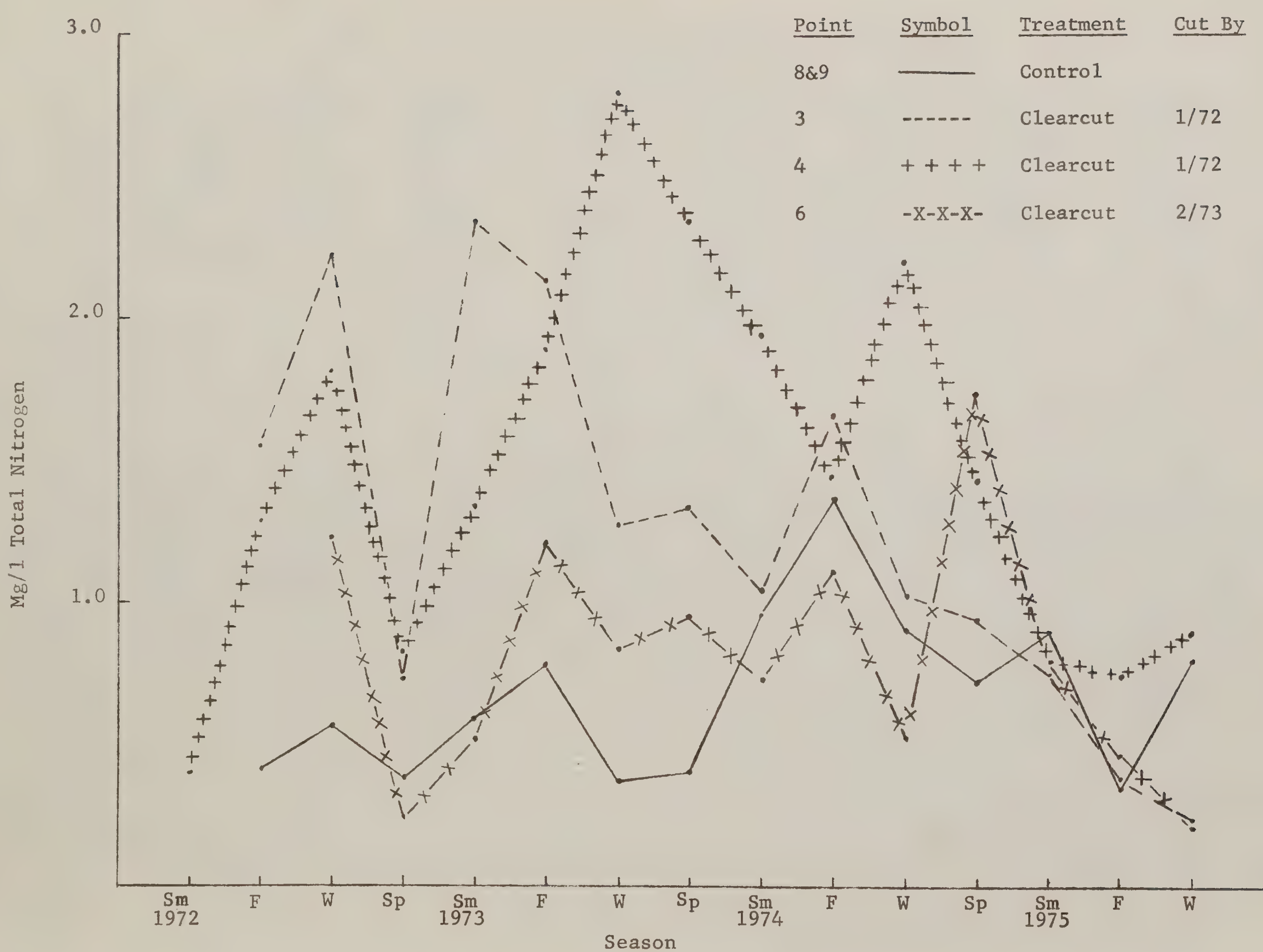

Figure 6. Mean Seasonal Total Nitrogen - Clearcuts

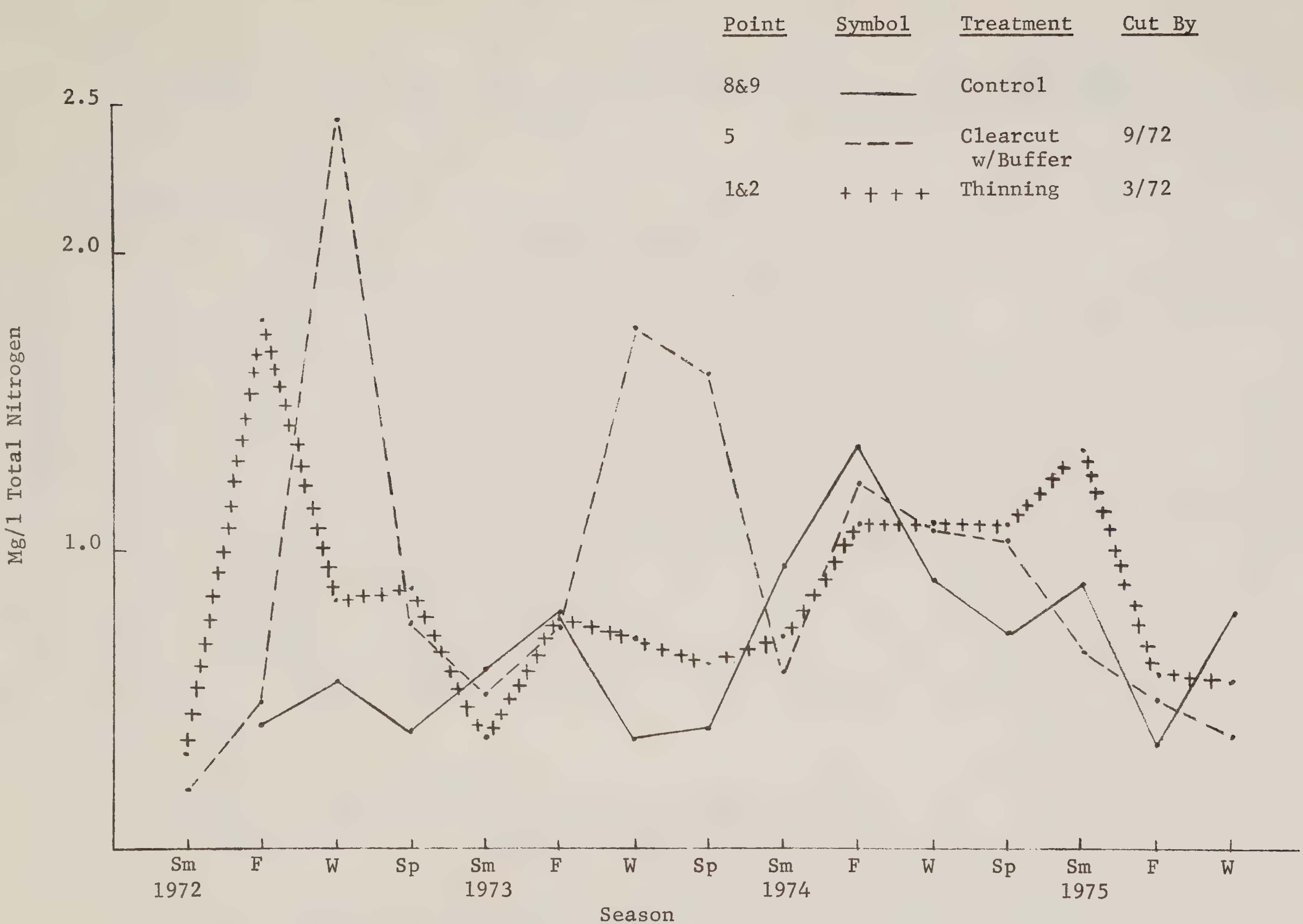

Figure 7. Mean Seasonal Total Nitrogen - Other Cuts

Figure 8. Mean Seasonal Total Nitrogen - Main Stream

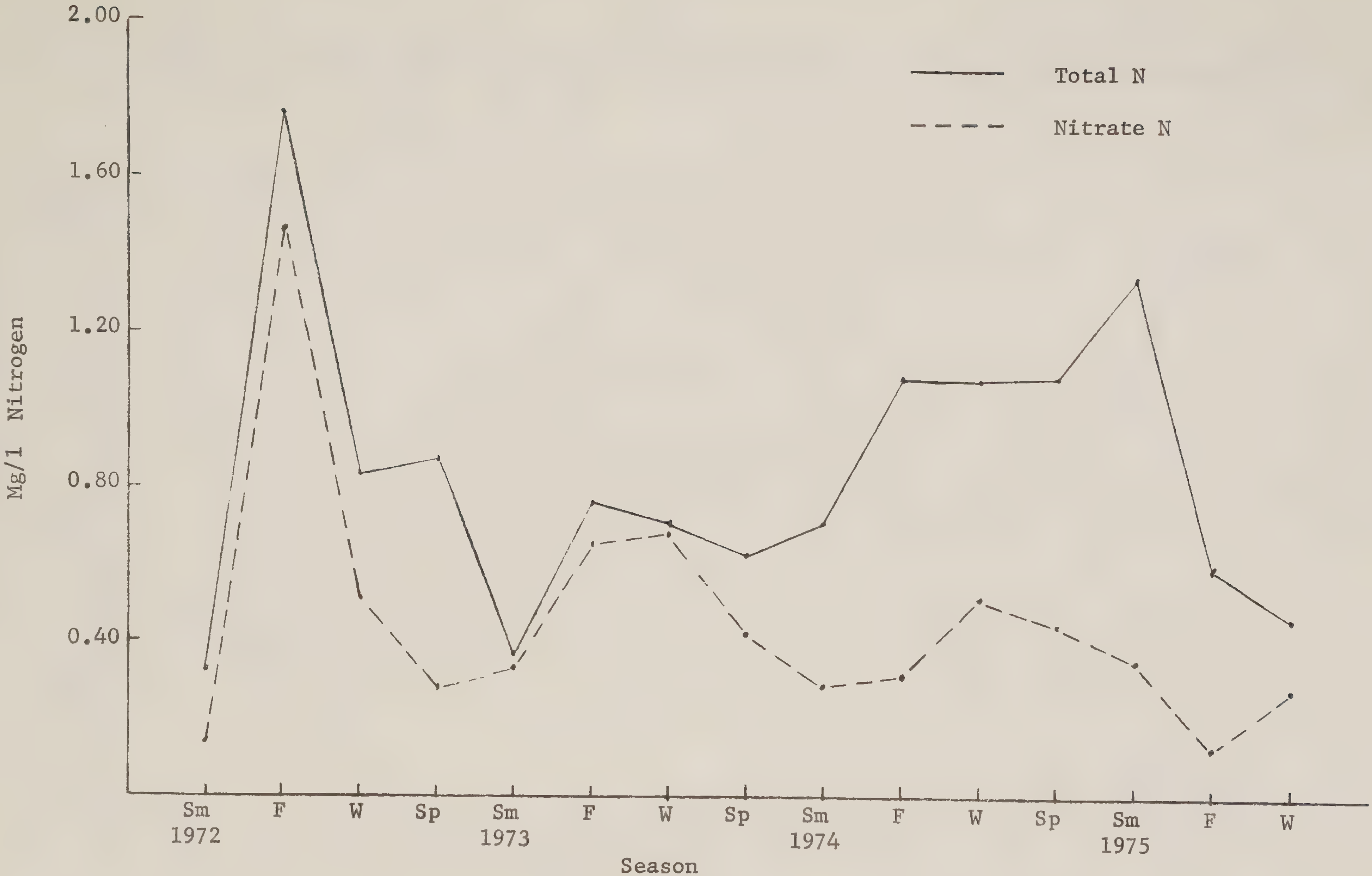

Figure 10. Mean Seasonal Nitrate and Total Nitrogen - Thinnings (1 & 2)

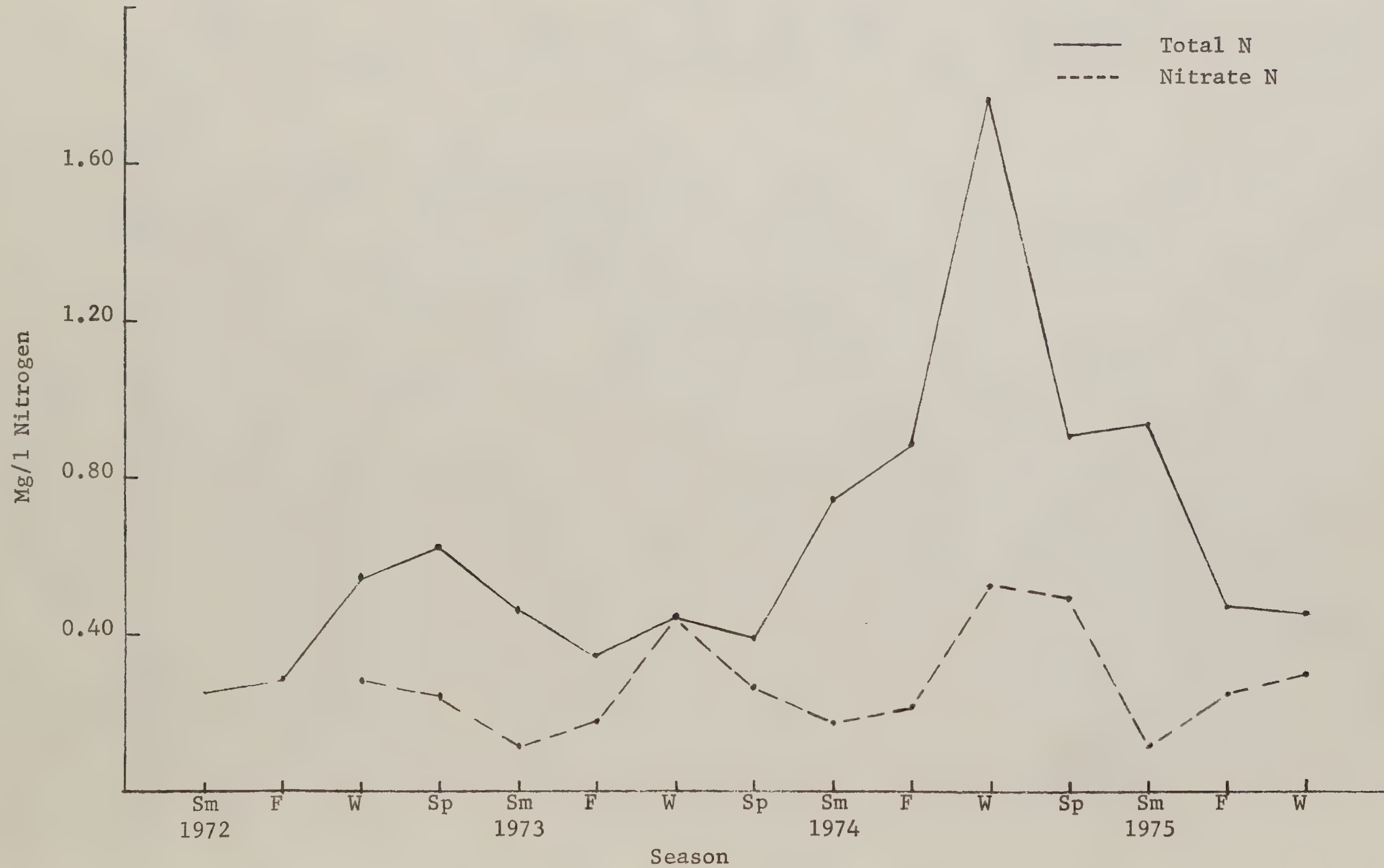

Figure 9. Mean Seasonal Nitrate and Total Nitrogen - Upstream (C)

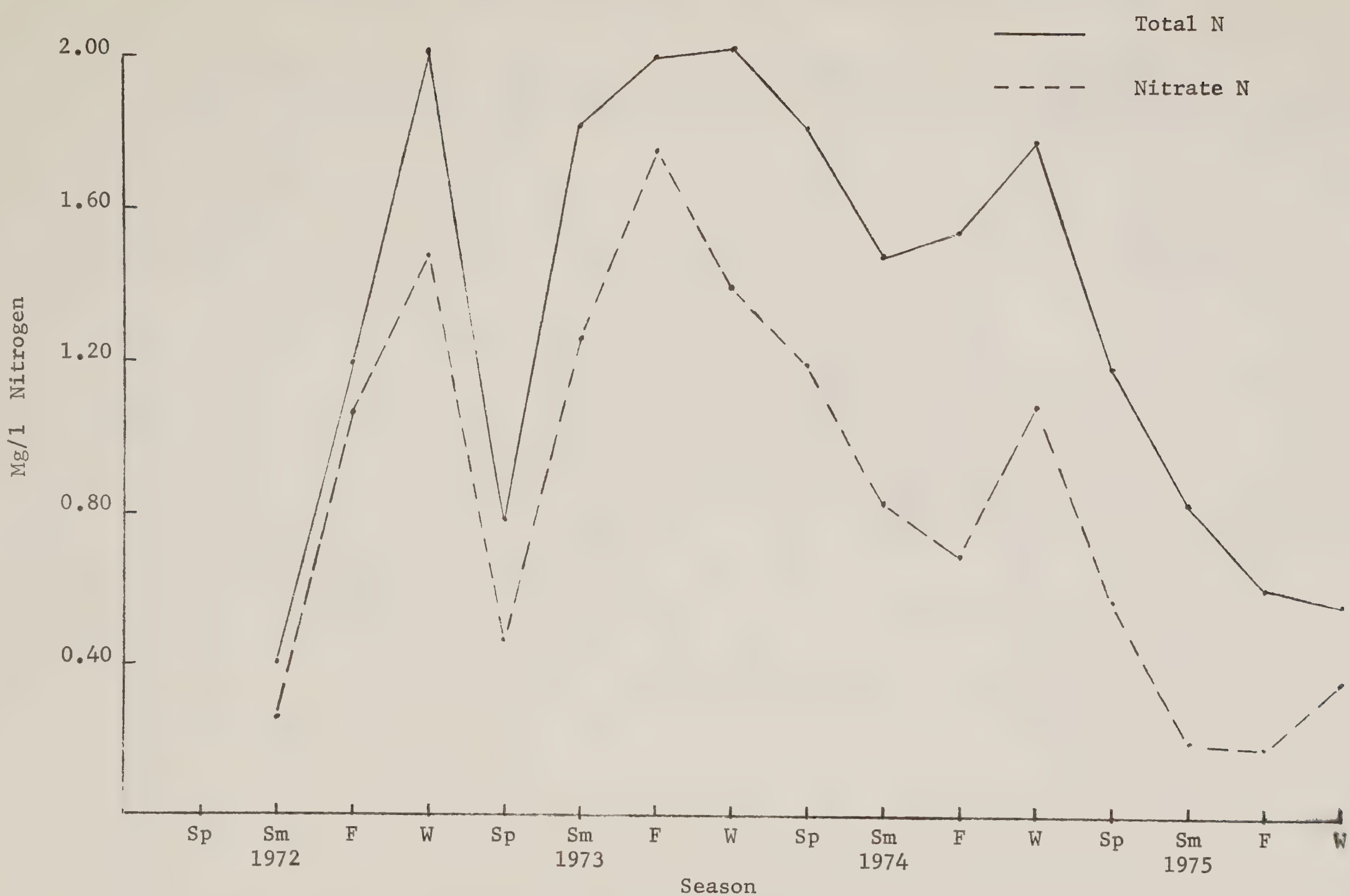

Figure 11. Mean Seasonal Nitrate and Total Nitrogen - Clearcuts (3 & 4)

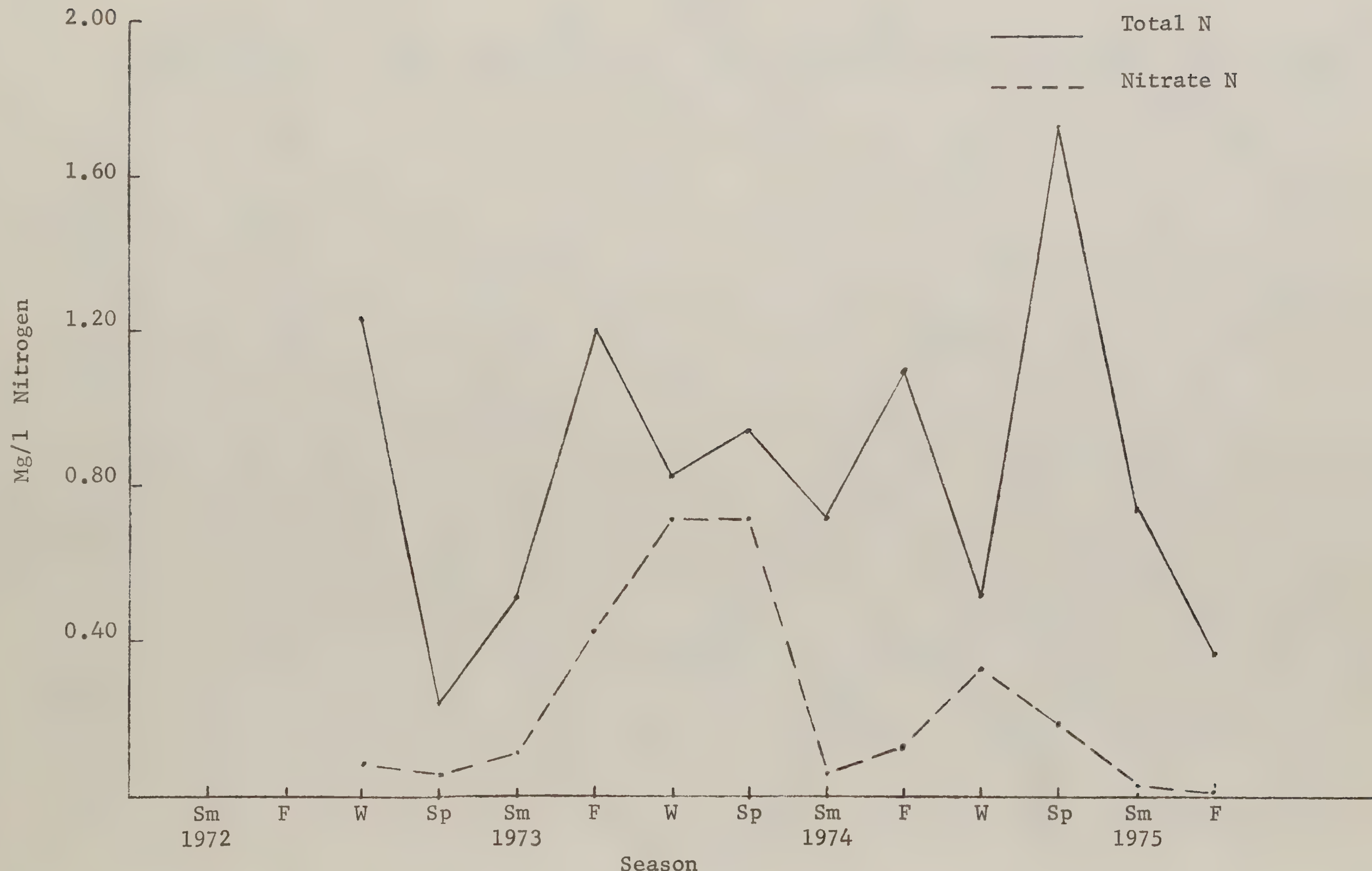

Figure 12. Mean Seasonal Nitrate and Total Nitrogen - Clearcut (6)

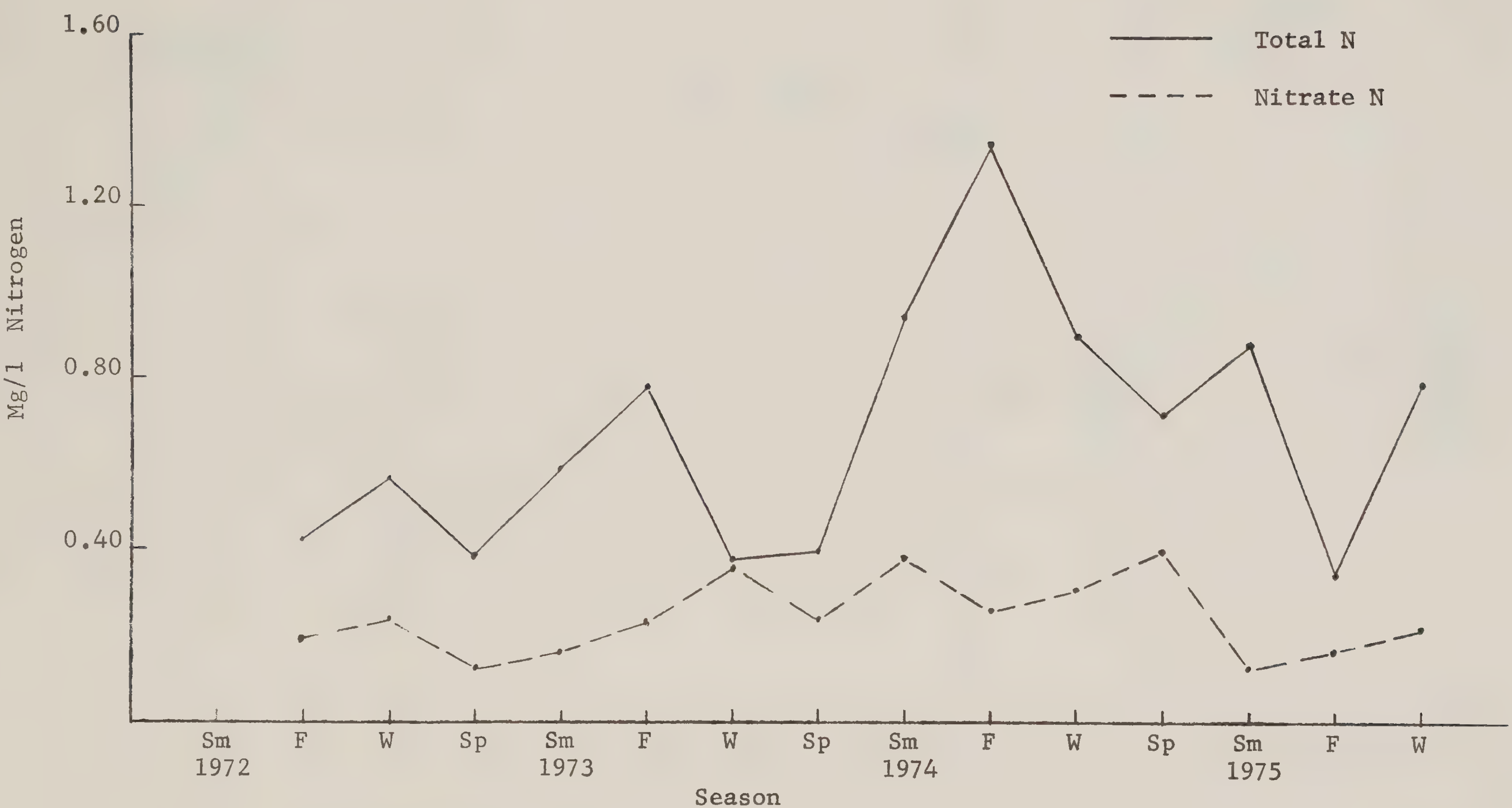

Figure 13. Mean Seasonal Nitrate and Total Nitrogen - Control (8&9)

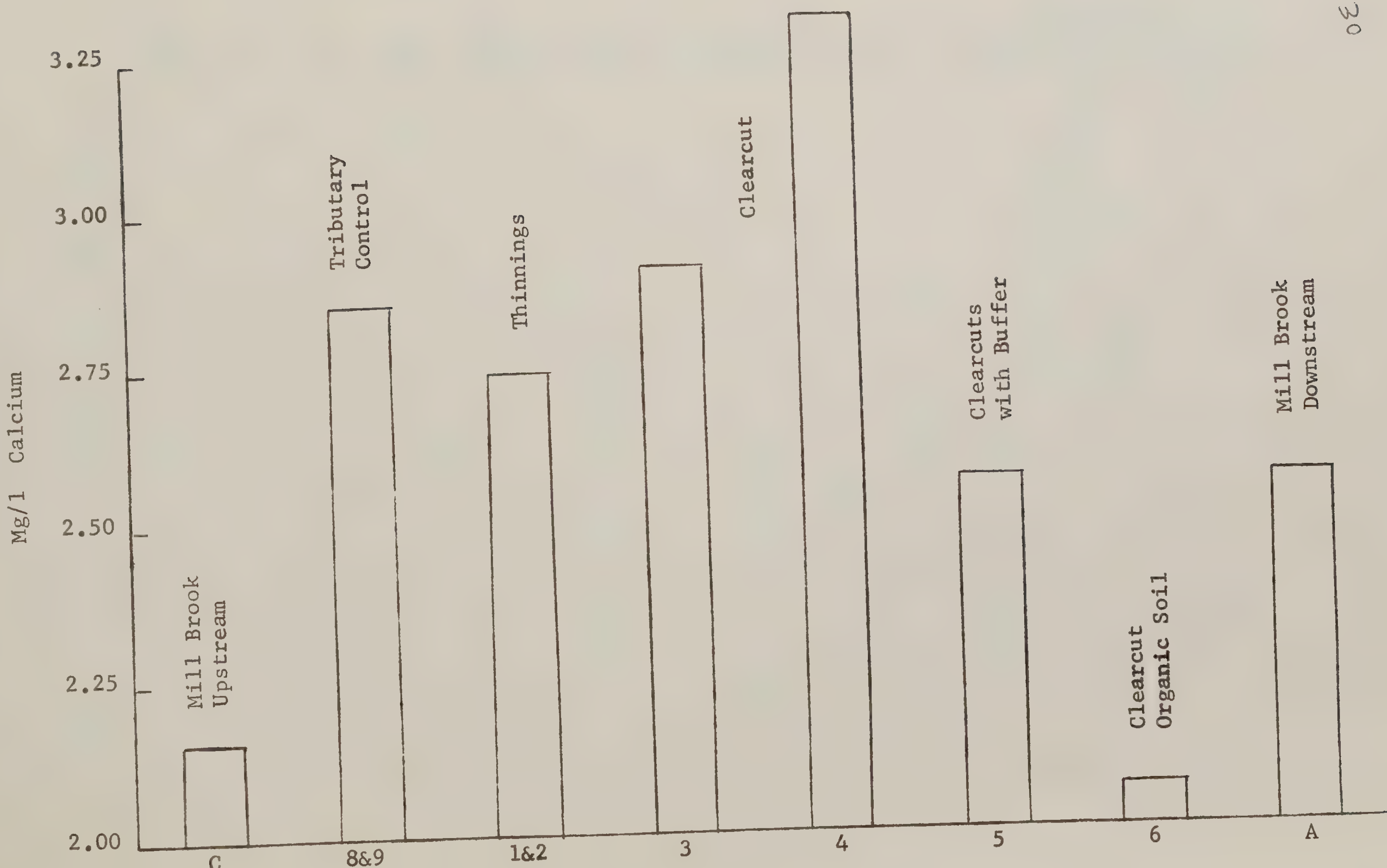

Figure 14. Three Year Mean Calcium

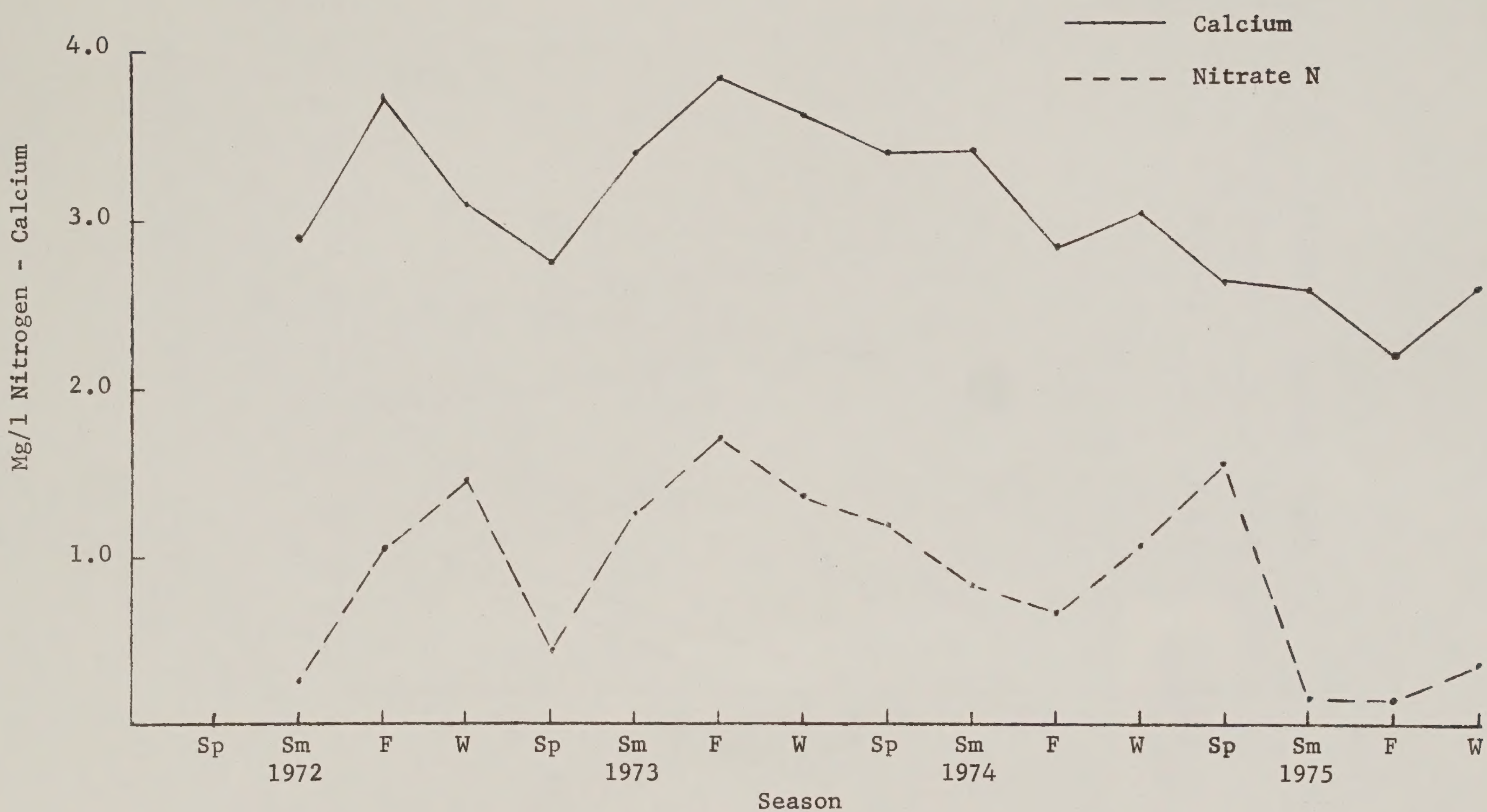

Figure 15. Mean Seasonal Calcium and Nitrate Nitrogen - Clearcut (3 & 4)

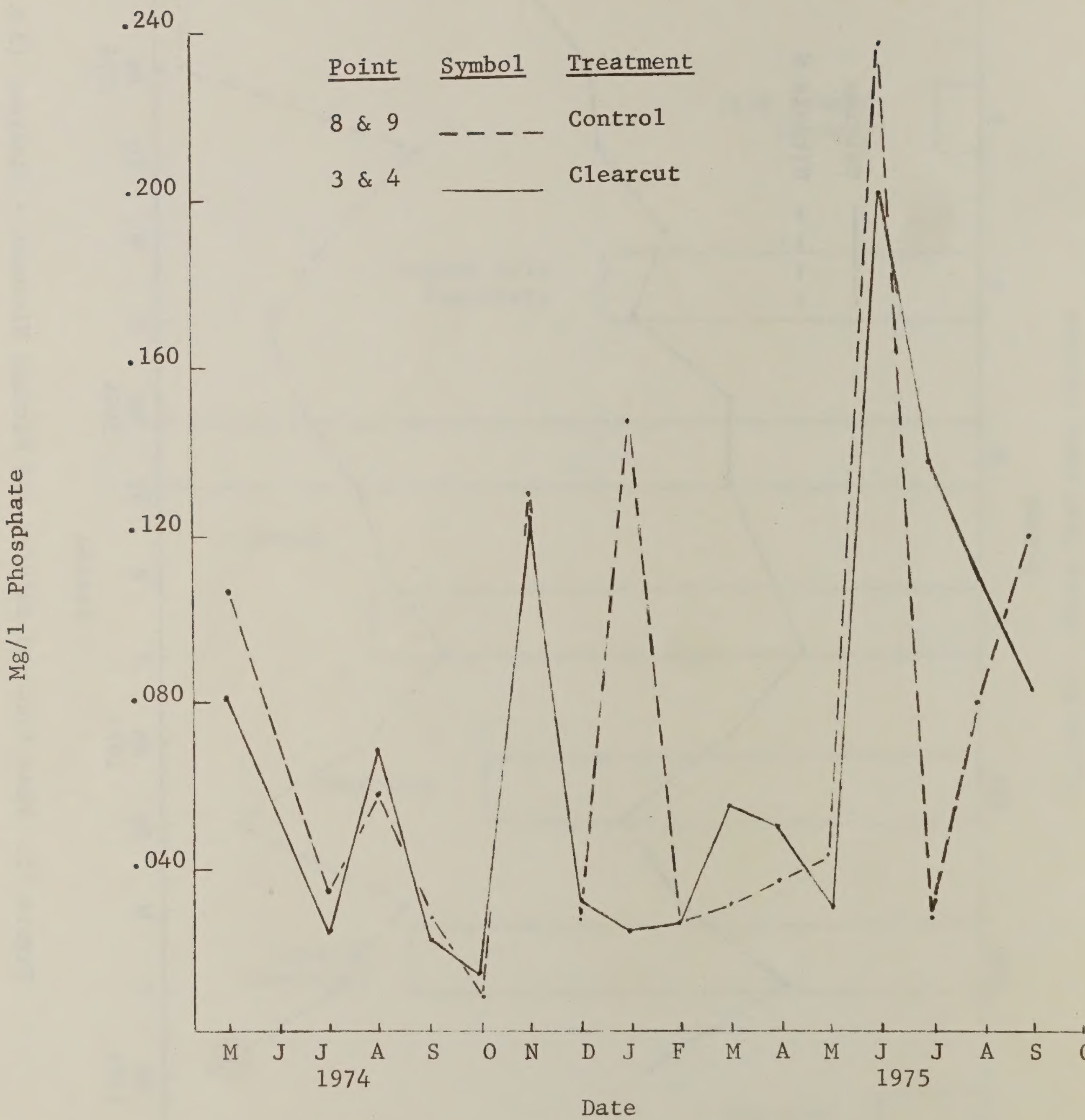

Figure 16. Monthly Phosphate - Clearcut

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